

**POWER SUPPLY SYSTEM AND METHOD USING
ANALOG COUPLING CIRCUITRY FOR
POWER-LINE COMMUNICATIONS**

PRIORITY

This application claims priority from Provisional Application, Serial No.60,413,292, filed September 25, 2003.

BACKGROUND OF THE INVENTION

5 Field of the Invention

The present invention relates to power-line communications (PLC) networking in general and particularly to the design of a power supply with built-in analog coupling to allow simplified integration of PLC devices within a host device.

10 Description of Related Art

Techniques for home networking over residential power lines have received considerable attention in recent years. The HomePlug Powerline Alliance, for example, has established a high-speed networking standard, and to date several manufacturers are producing and marketing PLC devices for the consumer market that are
15 interoperable under HomePlug standards.

A typical system **10** in which a consumer employs PLC devices **12, 14** is depicted in Fig. 1. Each of two hosts **16, 18** being networked are connected to the respective PLC devices **12, 14** that are in turn connected to residential power-line network **20**. Each PLC device **12, 14** incorporates (i) a digital processor **22**, (ii) an
20 analog front end (AFE) **24**, and (iii) power-line coupling circuitry **26** for receiving the

power line **28**. A connection **17, 19** between each host **16, 18** and the respective PLC device **12, 14** exists for communication purposes only; thus, if a host **16,18** also requires power from the residential power-network **20** (for example, if a host is a Personal Computer, a Printer, a DSL or Cable Modem, etc.) there must exist a second
5 connection **30** from the host **16, 18** to the power-line **28** for the purpose of providing electrical power to the host device. In the exemplary Power Line Network of Fig.1, one Host **16** has an internal power supply **31**, and the second Host **18** has an external power supply **33**. The present invention applies to both types of power supplies.

Summary of the Invention

10 In accordance with this invention, an internal or external power supply of the type used as a power supply for an electronic device that is a host for a PLC device incorporates passive coupling circuitry necessary to interface the power line to the AFE section of a PLC device. A passive coupling circuitry (coupler) is used with any PLC devices in the system to connect the communication signal to the power line. The
15 coupler is designed to pass any high-frequency communication signals and rejects the line 60 Hz (50Hz) power. The coupler also provides a first level of transient protection to the PLC device. By including the coupling circuitry in the host's power supply, a PLC device is simplified to now contain the digital processing and an AFE. For example, as shown in Fig. 2, after the incorporation of the present invention in the scenario of Fig.
20 1, two host devices **12, 14** can be connected to the residential power line **20** via a single path **32** through a coupler **34** according to this invention, as opposed to the two power-line connections **28, 30** required in the scenario of Fig. 1.

DESCRIPTION OF THE DRAWING

A better understanding of the present invention can be obtained when the following detailed description of a preferred embodiment is considered in conjunction with the drawings, in which:

5 Fig. 1 is a block diagram of a prior art PLC system.

 Fig. 2 is a simplified block diagram illustrating a PLC system according to the present invention.

 Fig. 3 is a block diagram of an exemplary host system (for example, a personal computer, printer, DSL or Cable Modem) employing the invention, i.e., an internal power supply that incorporates the power-line communications signal coupling and a
10 PLC device that connects to the power-line via the power supply.

 Fig. 4 is a diagram of a preferred embodiment of a power supply that includes the passive power-line coupling circuitry in accordance with the invention.

 Fig. 5 is a functional diagram of circuitry for combining/separating the power-line
15 communications signal and the DC power signal.

 Fig. 6 is a diagram of an exemplary host system (for example, a notebook computer, printer, DSL or Cable Modem) employing the invention, i.e., an external power supply that incorporates the power-line communications signal coupling and a PLC device that connects to the power-line via the power supply. The exemplary
20 system also utilizes circuitry for combining and separating a DC power signal and a power-line communications signal.

Fig. 7 is a diagram of a preferred embodiment of a power supply that includes the power-line coupling circuitry, as well as circuitry to combine/separate the power signal and communications signal.

Fig. 8 is a diagram of a preferred embodiment of a circuitry for
5 combining/separating the power signal and communications signal in the host device.

DETAILED DESCRIPTION

Referring to Fig. 3, a host system **106** incorporates a power supply **108** that connects to the residential power line **100** through a line terminal **102** and a neutral terminal **104**. The power supply **108** is constructed in accordance with the present invention and thus contains power-line coupling circuitry **112** in addition to the conventional system power source **110**. The system power source typically delivers DC power to the host electrical circuitry **114** as well as the PLC device **116**. The power delivery should be unaffected by the addition of the power-line coupling circuitry **112** to the power supply **108**. The PLC device **116** consists of an AFE **118** and a Digital Processor **120**. The AFE **118** interfaces to the coupling circuitry that is now part of the host power supply **108**, and performs the D/A (digital-to-analog) and A/D (analog-to-digital) conversion as well as to implement various transmit or receive filtering functions and gain stages on the analog side. The digital processor **120** contained in the PLC device, also performs both transmit and receive functions, and interfaces to a host controller **122** which either provides it data for transmission or accepts received data from the PLC device's digital processor **120**. The digital data may, for example, represent Internet data, streaming audio or video.

An additional benefit of the invention is that with the removal of coupling circuitry from the PLC device, no UL certification of the PLC device is required. It is the power supply that is burdened with UL certification, however a power supply must comply with UL specifications in any case, and the addition of the coupling circuitry should not represent an issue in this respect.

A preferred embodiment of the passive power-line coupling circuitry is shown in Fig. 4. The power-line coupling circuitry shares on one side the line and neutral wires (**102** and **104** in Fig. 3) that connect to the residential power line, but provides a second set of connections (**128** and **130** in Fig. 3) to serve as an interface from the power supply to the PLC device.

Referring to Fig. 4, the schematic of the passive power-line coupling circuitry is shown.

The line and neutral wires **102** and **104** connect to the residential power line. The capacitor **202** and the primary of transformer **204** form a high pass filter, allowing the power-line communications signal to pass and rejecting the line frequency (50 or 60 Hz). The two diodes **206** and **208** provide transient protection to the PLC device.

The power supply of Fig. 4 provides separate connections for the DC power signal across lines **124** and **126**, and for the communication signal across lines **128** and **130**. In some instances it may be advantageous to combine the two signals inside the power supply and provide a single connection. This may, for example, be the case if the power supply is to be deployed external to the host device, but only one signal cable is provided between the external power supply and the host device. Additional circuitry is then required to combine the power and communication signals in the power supply and potentially to separate the power signal and the communication signal on the side of the PLC device. Such circuitry is readily derived, but may vary considerably according to the requirements of the particular power supply or host

device. Conceptually, such circuitry is described by the embodiment illustrated in Fig. 5.

A circuit as depicted schematically in Fig. 5 may be incorporated both in the power supply and in the host device to combine and separate the DC power signal and the power line communications signal. Fig. 6 is a diagram of a preferred embodiment of the invention including the Combiner/Separator circuitry, with a host device that utilizes an external power supply.

A preferred embodiment of an external power supply with circuitry **50** for combining/separating the power signal and communications signal is depicted in Fig. 7. Fig. 8 depicts a preferred embodiment of circuitry **70** that can be integrated in a host device as shown by example in Fig. 6. The circuitry **50** depicted in Fig. 7 contains two different transformers T1 and T2. T2 is used as part of a low voltage power supply. This is an unregulated linear power supply with a DC output, but the concept applies equally to any switched power supply that has a low voltage output. Signal coupling transfer T1 couples the signal from a power-line to the power supply cable **56**. The signal being transferred across T1 can be treated as a differential signal that is centered on a neutral value. The neutral value used is the low voltage output of the power supply, which is injected onto the secondary (right hand) side of the transformer with a center tap. The secondary side of transformer T1 contains both an AC signal and the low voltage current necessary to operate a host device, such as depicted in Fig. 2 and described with reference thereto.

A three wire cable **52** connects the power supply of Fig. 7 to corresponding circuitry incorporated in the host device. One wire is ground. The other two wires are

redundant carriers of the low voltage DC power signal, and carriers of the differential power-line communications signal.

In the preferred embodiment of the host device circuitry **70** of Fig. 8, a transformer T500 couples the differential communication signals off of the signal wire pair **72** from Powerjack J500. This pair **72** can also be center tapped to extract a low-voltage DC current without shorting the differential communication signals.

The design in the preferred embodiments of Fig. 7 and Fig. 8 has several advantages over other power-line signal coupling methods. The communication signals are injected onto a redundant set of low voltage DC wires instead of between a low voltage wire and ground, which saves the necessity for high quality inductors to isolate the communication signals from the low impedance between power and ground connection in the low-voltage power supply. Such high quality inductors are expensive and not readily available in large quantities. When such inductors have been improperly substituted with lesser quality parts, the communications performance of a prior art device has been reduced.

The embodiment of Figs. 7 and 8 also minimizes the cost added to a conventional power supply. The same power supplies can be used with several products. Compared with a host device that utilizes an internal power supply, the embodiment represented with Figs. 7 and 8 has the advantage of removing the power supply's space and heat dissipation requirements from inside the host device.